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RESEARCH MEMORANDUM

CHARACTERISTICS OF FLAP-TYPE SPOILER AILERONS AT VARIOUS LOCATIONS ON A 60° DELTA WING WITH A DOUBLE SLOTTED FLAP

By Delwin R. Croom

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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CHARACTERISTICS OF FLAP-TYPE SPOILER AILERONS AT VARIOUS LOCATIONS ON A 60° DELTA WING WITH A DOUBLE SLOTTED FLAP

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SUMMARY

A low-speed wind-tunnel investigation was made to determine the static lateral control characteristics of flap-type spoiler ailerons on a thin delta wing equipped with a double slotted flap. The model was a flat plate with beveled leading and trailing edges, a maximum thickness ratio of 0.045, 60° sweepback at the leading edge, and an aspect ratio of 2.31.

The results of the investigation indicated that a spoiler located on the flap gave rolling-moment coefficients that varied fairly linearly with spoiler projections and were about the same magnitude for either the flap-retracted or the flap-deflected condition. Spoilers located just ahead of the double slotted flap were very powerful but had unsatisfactory variations of rolling-moment coefficient with spoiler projection and spoiler spans.

INTRODUCTION

Considerable interest is being shown in the use of delta wings for high-speed airplanes because this plan form shows some desirable aerodynamic and structural characteristics. Results of previous investigations (refs. 1 and 2) indicate that, by employing double slotted flaps on a 60° delta wing, the angle of attack necessary to obtain a given lift coefficient was considerably reduced, thereby making the use of double slotted flaps desirable for the landing condition. Reference 3 indicates that spoiler-type controls employed on the delta wing provided good lateral control for the unflapped-wing configuration. With these considerations in mind, an investigation was made in the Langley 300 MPH 7- by 10-foot tunnel to determine spoiler configurations that would provide adequate lateral control for the flapped wing as well as the unflapped wing. The model used to determine the static lateral control characteristics in the investigation was a flat plate with beveled leading and trailing edges, a maximum thickness ratio of 0.045, 60° sweepback at the leading edge, and an aspect ratio of 2.31.

COEFFICIENTS AND SYMBOLS

The results of the tests are presented as standard NACA coefficients of forces and moments about the stability axes. Pitching-moment coefficients are given about the wing 25-percent mean-aerodynamic-chord point shown in figure 1. The positive directions of forces, moments, and angles are shown in figure 2.

The coefficients and symbols are defined as follows:

C_L lift coefficient, $\frac{\text{Lift of model}}{qS}$

C_D drag coefficient, $\frac{\text{Drag of model}}{qS}$

C_m pitching-moment coefficient, referred to 0.25 $\bar{c}$, $\frac{\text{Pitching moment}}{qS\bar{c}}$

C_l rolling-moment coefficient, $\frac{\text{Rolling moment caused by spoiler projection}}{qSb}$

C_n yawing-moment coefficient, $\frac{\text{Yawing moment caused by spoiler projection}}{qSb}$

b wing span, 4.00 ft

c local wing chord, ft

$\bar{c}$ wing mean aerodynamic chord, 2.31 ft., $\frac{2}{S}\int_0^{\frac{b}{2}} c^2 dy$

S wing area, 6.93 sq ft

t	local wing thickness, ft
y	lateral distance from plane of symmetry, measured parallel to Y-axis, ft
δ_f	flap deflection measured perpendicular to hinge line, deg
δ_v	vane deflection measured perpendicular to hinge line (along flat lower surface of vane), deg
α	angle of attack of wing, deg
q	free-stream dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
V	free-stream velocity, ft/sec
ρ	mass density of air, slugs/cu ft
L'	rolling moment, ft-lb
N	yawing moment, ft-lb
M	pitching moment, ft-lb
L	lift, lb
D	drag, lb

Subscripts:

i	inboard
o	outboard
r	root

MODEL AND APPARATUS

The model was tested on the single support strut in the Langley 300 MPH 7- by 10-foot tunnel. The model was mounted in the center of the tunnel and was pivoted in pitch at the 25-percent mean-aerodynamic-chord point projected on the plane of symmetry as shown in figure 1. The strut was connected to a balance system from which the aerodynamic forces and moments were measured. A small fuselage was used in the investigation to cover the strut support linkages and does not necessarily represent a typical fuselage.

The wing of the model had a 60° apex angle, an aspect ratio of 2.31, and a taper ratio of 0 (fig. 1 and table I). The model was made from a flat steel plate 5/8 inch thick, with beveled leading and trailing edges. The thickness ratio varied linearly from 1.5 percent chord at the root to 4.5 percent chord at 0.67b/2, and it remained constant at 4.5 percent chord from 0.67b/2 to the tip.

The double-slotted-flap configuration used for this investigation (fig. 3) is configuration X-E of reference 2. The flap had a constant chord of 5.49 inches, a span of 0.67b/2 and an area equal to approximately 17.6 percent of the total wing area. The flap consisted of a brass leading edge (constructed to the ordinates given in table II) attached to a steel wedge. The vane was constructed of steel to the ordinates given in table III.

The spoilers used in this investigation, which were made of wood, were mounted on the left semispan and had a span equal to the flap span, except the segmented spoiler for which the span was varied. The cross-sectional dimensions and locations of the hinge axes are shown in figure 3. Another spoiler configuration investigated was made by deflecting the slot lip (fig. 3).

TESTS

The tests to determine the lateral control characteristics were made in the Langley 300 MPH 7- by 10-foot tunnel at a dynamic pressure of approximately 25 pounds per square foot, corresponding to an airspeed of about 100 miles an hour. Reynolds number for this airspeed, based on the mean aerodynamic chord of the model (2.31 ft), was approximately 2.1×10^6. The corresponding Mach number was 0.13. The tests were run through an angle-of-attack range of approximately -10° to 32°. The spoilers were located at three chordwise positions and varied in projection from $0.01\bar{c}$ to $0.0866\bar{c}$. An $0.0866\,\bar{c}$ spoiler was varied spanwise and the slot lip was also deflected as a spoiler.

CORRECTIONS

The jet-boundary corrections applied to the data of this paper were obtained by the method outlined in reference 4. Jet-boundary corrections applied are as follows:

$$\Delta\alpha = 0.638C_L$$

$$\Delta C_D = 0.011(C_L)^2$$

Corrections for tunnel blockage and buoyancy are negligible and were therefore not applied to these data.

RESULTS AND DISCUSSION

Aerodynamic Characteristics of the Wing

The lift, drag, and pitching-moment characteristics of the plain and flapped wings are given in figure 4. No discussion of these data is given since they are discussed in detail in reference 2.

The effects of spoiler projection on the aerodynamic characteristics of the plain wing and the wing with the double slotted flap deflected are presented in figures 5 to 11.

Chordwise spoiler location had little effect on the incremental loss in lift coefficient due to spoiler projection for the flap-retracted condition (figs. 5 and 6 and ref. 3) but had large effects when the flap was deflected (figs. 7 to 11). When the spoiler was hinged at the forward position (ahead of the flap) large losses in lift occurred with spoiler projection, whereas when the spoiler was hinged at the intermediate and rearward positions (on the flap) much lower loss in lift occurred. Deflecting the slot lip up resulted in large losses in lift coefficient but a down deflection of the slot lip had only small effect on the lift coefficient.

The drag data show that an increase in spoiler projection gives an increase in drag coefficient at constant lift coefficient for all configurations tested except for those where the spoiler was located on the deflected flap. In this case the spoiler had little effect on the drag coefficient below a lift coefficient of 1.10.

The pitching-moment data show that the spoilers produced a positive increment of pitching-moment coefficient but gave no appreciable change in the slopes of the pitching-moment curves.

Lateral Control Characteristics

The lateral control characteristics of the 60° delta wing are presented as the variation of rolling- and yawing-moment coefficients with angle of attack (figs. 12 to 18), variation of rolling-moment coefficient with spoiler projection (fig. 19), and variation of rolling-moment coefficient with spoiler span (fig. 20).

Flaps retracted.- The plain wing having a spoiler hinged at the intermediate position (fig. 12) had less variation of rolling-moment coefficient with angle of attack and also gave larger values of rolling-moment coefficient than when the spoiler was hinged at the forward position (fig. 13). This increased effectiveness of the more rearward spoilers is in good agreement with results of reference 3. The variation of rolling-moment coefficient with spoiler projection is nearly linear (at $\alpha = 0^{\circ}$) for spoilers located at either of the two chordwise stations (fig. 19(a)).

Flaps deflected.- Spoilers located ahead of the double slotted flap (hinge line at the forward position) or the slot lip produced large rolling-moment coefficients for small up projections (figs. 14 and 16). The variation of rolling-moment coefficient with spoiler projection was linear from $0.01\bar{c}$ to $0.0866\bar{c}$ spoiler projection (fig. 19(b)); however, a spoiler projection of $0.01\bar{c}$ produced 70 percent of the effectiveness obtained from a spoiler projection of $0.0866\bar{c}$. This effectiveness obtained from such small spoiler projections was much larger than previously encountered on straight or swept wings (refs. 5 and 6). The span of the forward spoiler was varied in hopes that a more desirable variation of rolling-moment coefficient could be obtained. The spoiler projection selected was that which produced the maximum rolling-moment coefficient for the unflapped wing; however, large values of rolling-moment coefficient were obtained for small spoiler spans (fig. 15), and the rolling-moment coefficient variation (at $\alpha = 0^{\circ}$) with spoiler span was also undesirable (fig. 20). When the spoiler was hinged at the intermediate position (fig. 17) and at the rearward position (fig. 18), the rolling-moment coefficients were less than those for spoilers located at the forward position, however, the variation of rolling-moment coefficient with spoiler projection was nearly linear (fig. 19(b)). Comparison of figures 19(a) and 19(b) showed that for the spoiler located at the intermediate position the effectiveness is about the same for the flap-retracted and the flap-deflected condition.

All double-slotted-flap configurations tested with spoilers projected experienced adverse yawing moments. The maximum yawing moment was greater (figs. 14 to 16) when the spoiler was hinged at the forward position than when the spoiler was hinged at either the intermediate position (fig. 17), or the rearward position, (fig. 18).

The plain wing equipped with spoilers hinged at the intermediate position experienced adverse yawing moments above approximately 8° angle of attack for all projections, whereas, with spoiler hinged at the forward position, adverse yawing moments were noted only for the $0.0866\bar{c}$ spoiler projection from 10° angle of attack to the stall.

CONCLUSIONS

On the basis of wind-tunnel tests of a spoiler-type control on a 60° delta wing with and without double slotted flaps the following conclusions were reached:

1. Spoilers located on the flap gave rolling-moment coefficients that varied fairly linearly with spoiler projection and were about the same magnitude for the flap-retracted or the flap-deflected condition.

2. Spoilers located just ahead of the deflected double slotted flap were very powerful but had unsatisfactory variation of rolling-moment coefficients with either spoiler projection or spoiler span.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

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2. Riebe, John M., and MacLeod, Richard G.: Low-Speed Wind-Tunnel Investigation of a Thin 60° Delta Wing With Double Slotted, Single Slotted, Plain, and Split Flaps. NACA RM L52J29, 1952.

3. Wiley, Harleth G., and Solomon, Martin: A Wind-Tunnel Investigation at Low Speeds of the Aerodynamic Characteristics of Various Spoiler Configurations on a Thin 60° Delta Wing. NACA RM L52J13, 1952.

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TABLE I

PHYSICAL CHARACTERISTICS OF THE TEST MODEL

Wing:	
Span, ft	4.00
Aspect ratio	2.31
Thickness of flat plate $\left(\left(\frac{t}{c}\right)_{max} = 0.045\right)$, in	5/8
Leading-edge sweep, deg	60.00
Area, sq ft	6.93
Mean aerodynamic chord, ft	2.31
Leading-edge angle, deg	6.8
Vane:	
Span, ft	2.70
Chord, ft	0.13
Chord, percent wing root chord	3.6
Chord, percent flap chord	27.4
Flap:	
Span, ft	2.70
Chord, ft	0.46
Chord, percent wing root chord	13.2
Area, sq ft	1.22
Area, percent wing area	17.6
Trailing-edge angle, deg	8.0

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TABLE II

ORDINATES OF THE BRASS LEADING EDGE OF THE TRAILING-EDGE FLAP

[All dimensions in inches]

Station x	Upper y	Lower y
0	-0.15	-0.15
.1	.01	-.25
.2	.08	-.27
.4	.18	-.29
.6	.25	-.30
.8	.30	-.31
1.1	.31	-.31

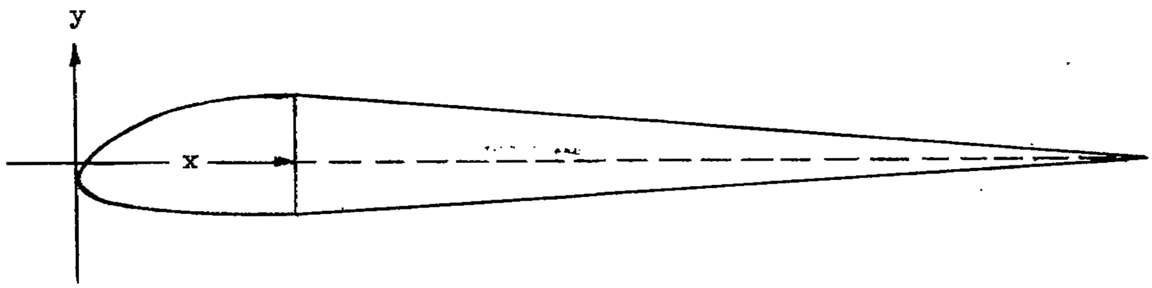

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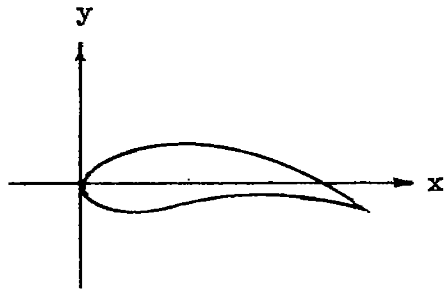
TABLE III

ORDINATES OF THE VANE



Station, x in.	Lower y	Upper y
0	0	0
.025	-.067	.051
.075	-.105	.100
.125	-.125	.130
.175	-.139	.153
.225	-.145	.175
.275	-.145	.190
.325	-.138	.205
.400	-.125	.219
.500	-.099	.221
.600	-.074	.215
.700	-.055	.205
.800	-.044	.180
.900	-.039	.153
1.000	-.042	.115
1.100	-.050	.075
1.200	-.066	.025
1.300	-.083	-.032
1.400	-.105	-.083
1.500	-.153	-.153

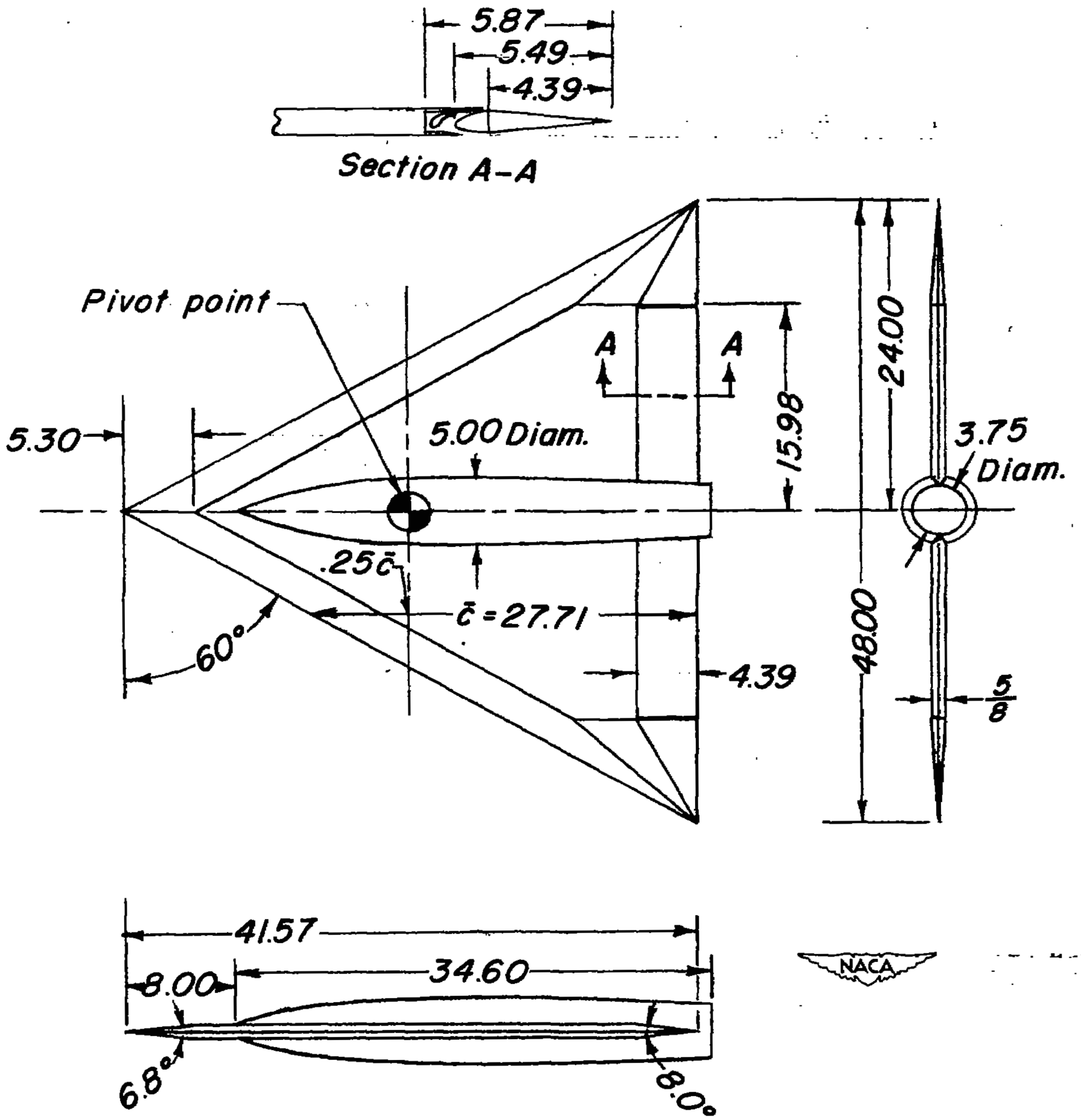


Figure 1.- General arrangement of 60°, delta-wing model. All dimensions are in inches.

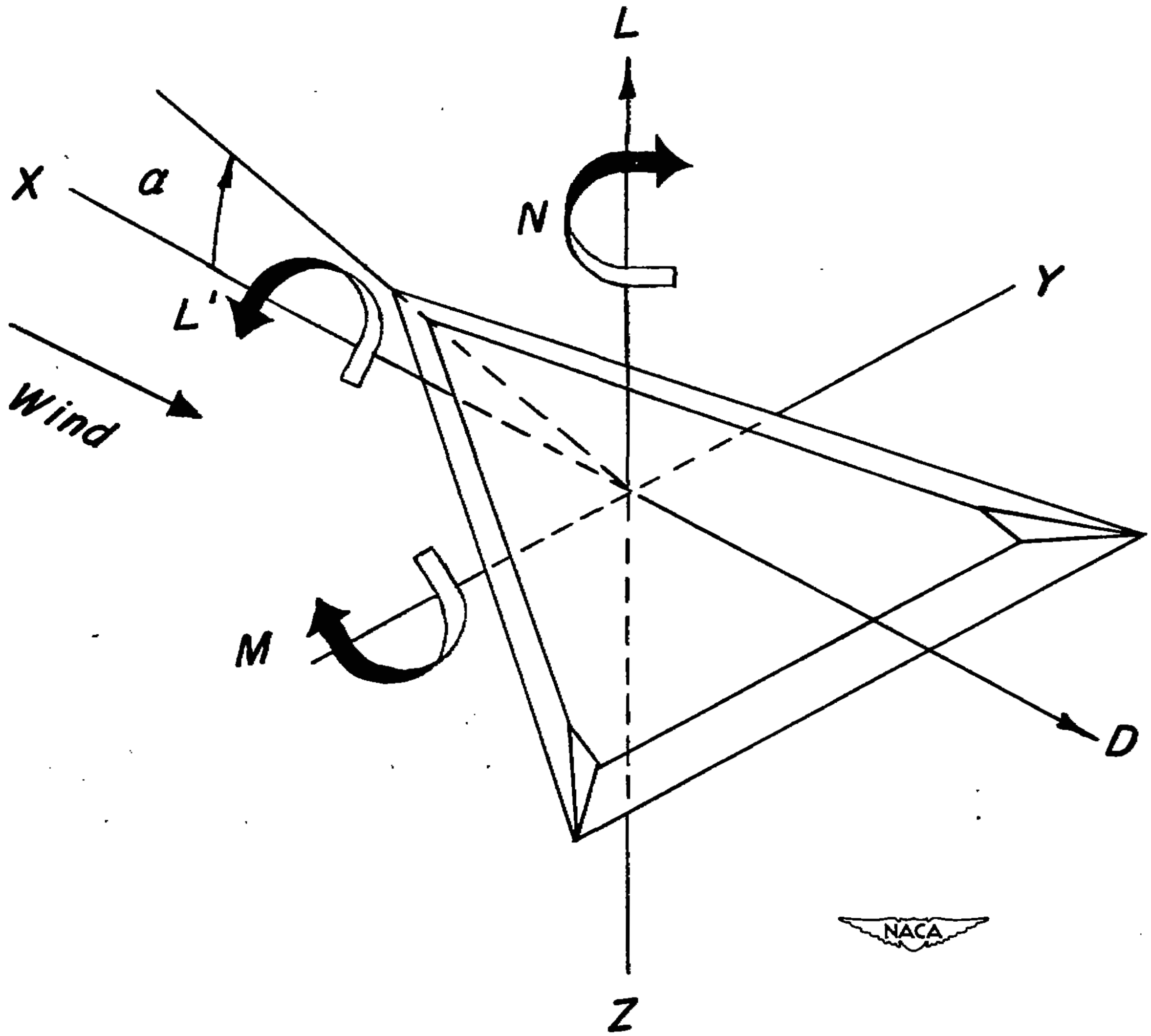


Figure 2.- System of stability axes. Positive directions of forces, moments, and angles are indicated by arrows.

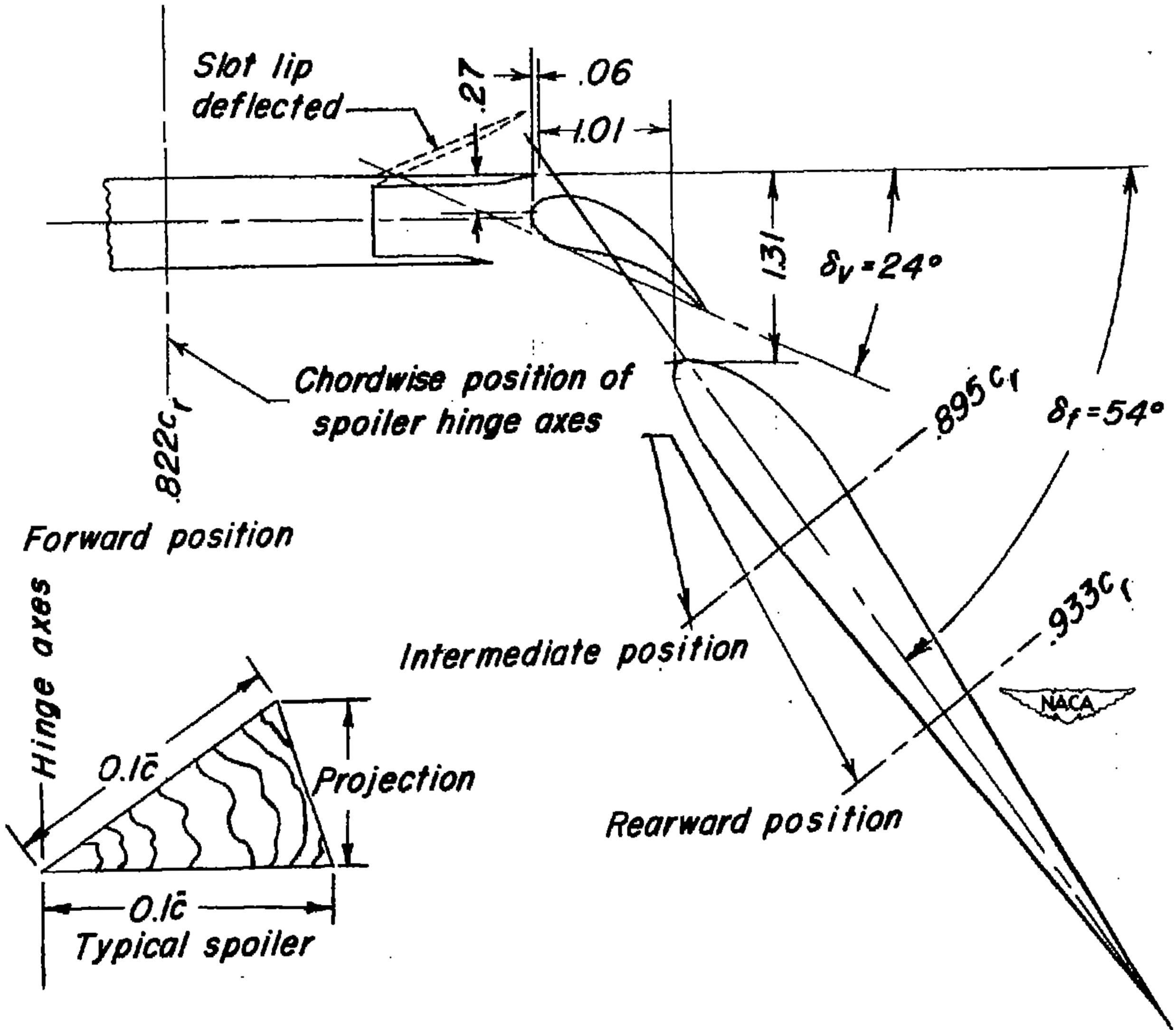


Figure 3.- Trailing-edge flaps and spoilers used on 60° delta-wing model and various spoiler locations. Dimensions are in inches unless otherwise noted.

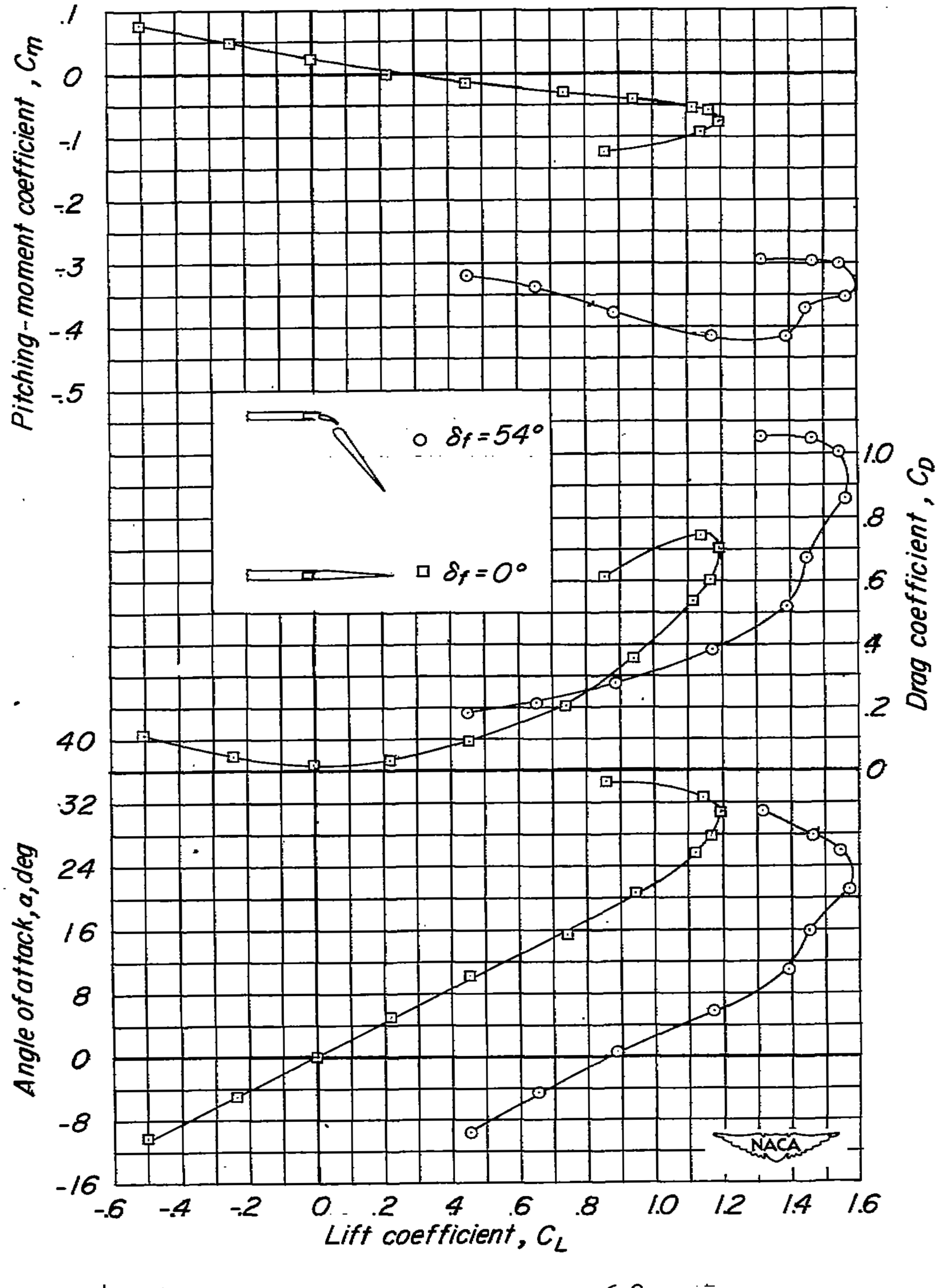


Figure 4.- Aerodynamic characteristics of 60° delta-wing model.

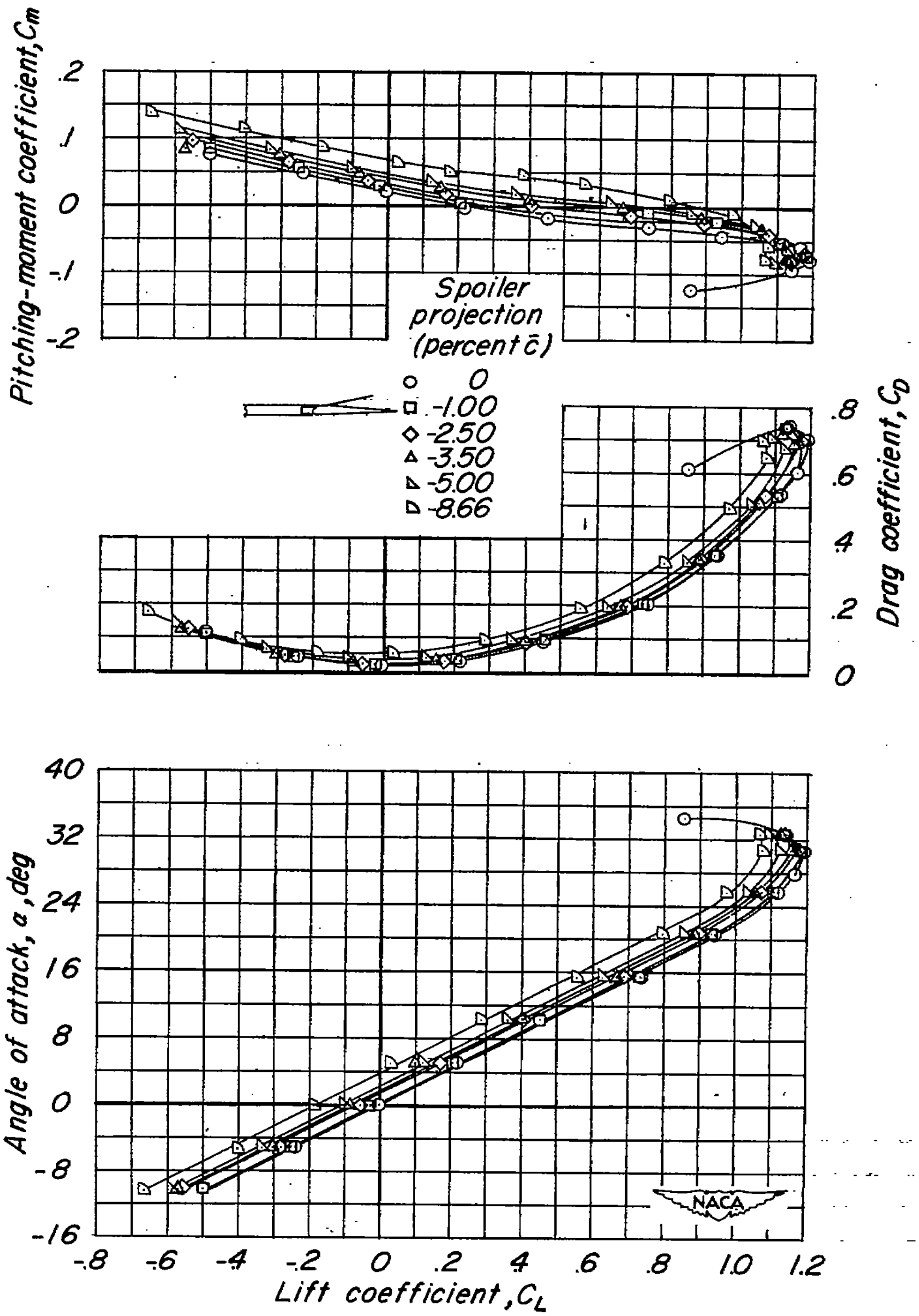


Figure 5.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model. Spoiler hinged at intermediate position and span extending from 0.094b/2 to 0.667b/2.

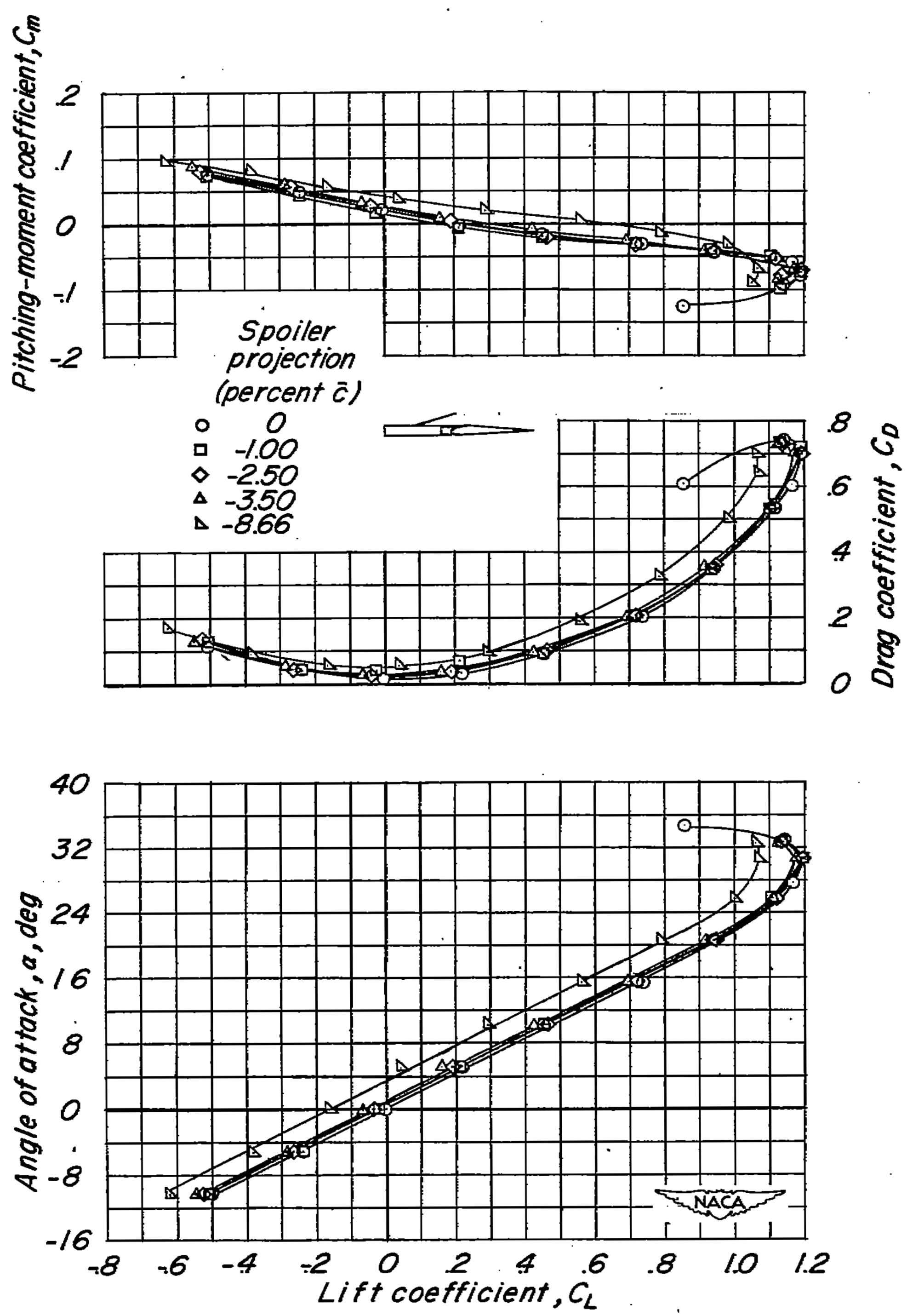


Figure 6.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model. Spoiler hinged at forward position and span extending from 0.094b/2 to 0.667b/2.

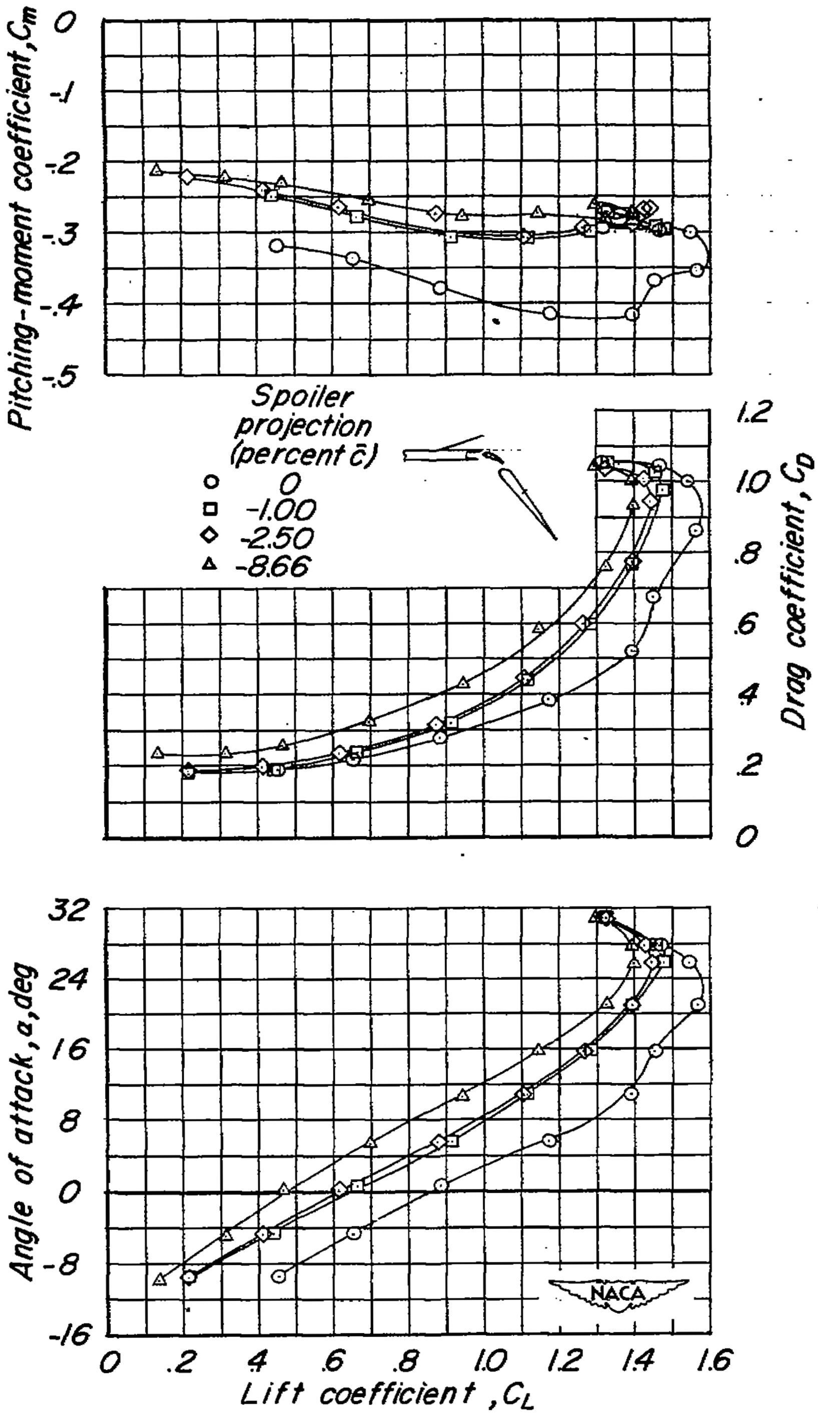


Figure 7.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54^\circ$). Spoilers hinged at forward position and span extending from 0.094b/2 to 0.667b/2.

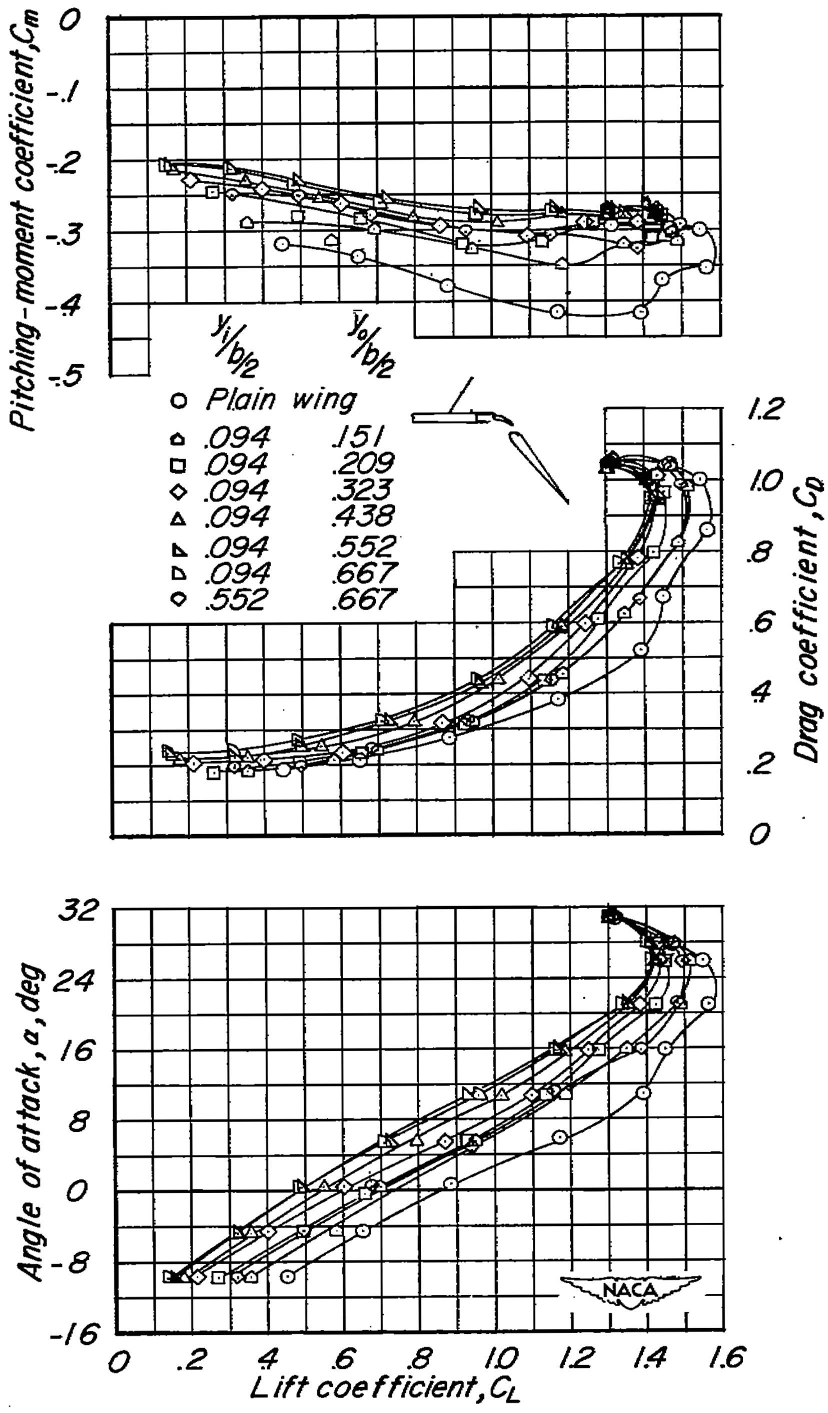


Figure 8.- Effects of spoiler span on aerodynamic characteristics of 60° delta-wing model with double slotted flaps (δ_f = 54°). Spoilers projected at 0.0866$\bar{c}$ and hinged at forward position.

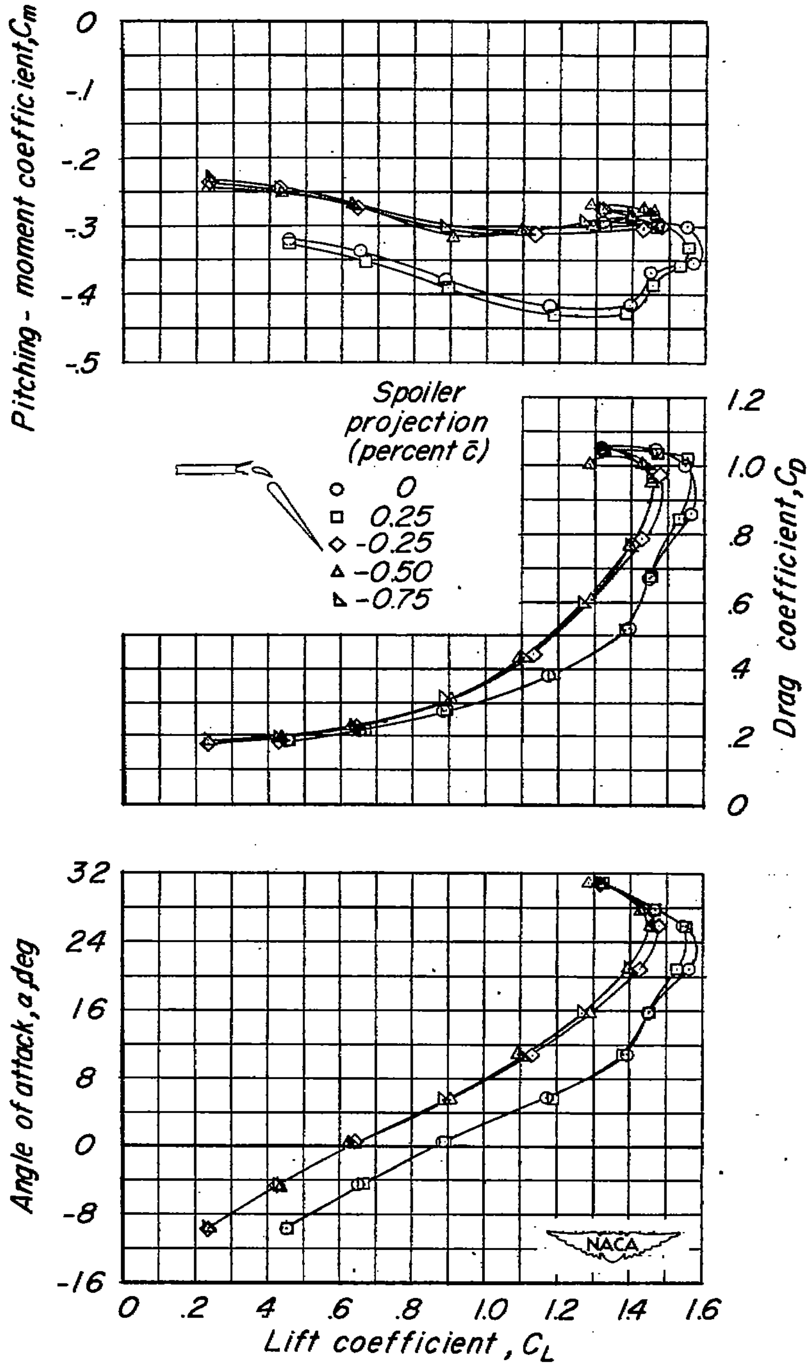


Figure 9.- Effects of deflecting lip of double-slotted-flap 60° delta wing ($\delta_f = 54°$) on aerodynamic characteristics. Lip located at 88.6 percent root chord line and span extending from 0.094b/2 to 0.667b/2.

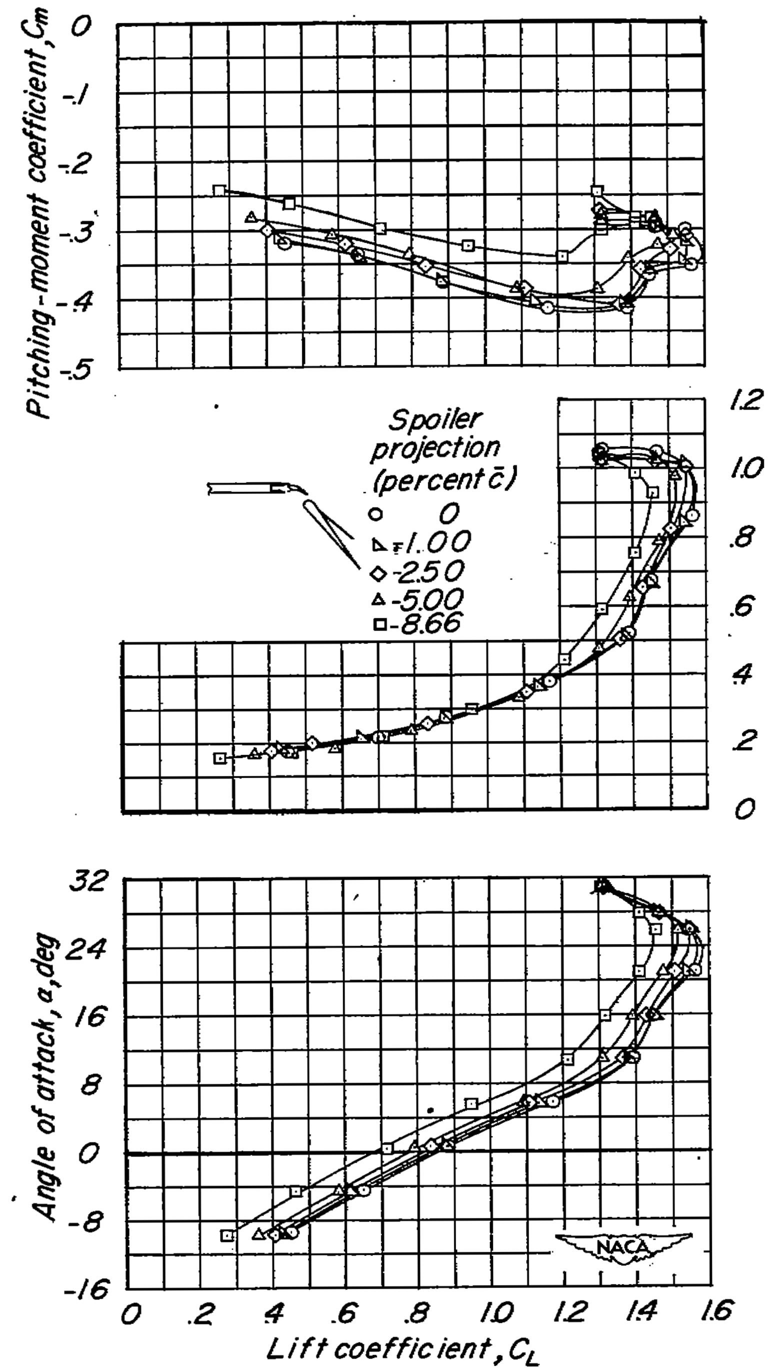


Figure 10.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54^\circ$). Spoiler hinged at intermediate position and span extending from 0.094b/2 to 0.667b/2.

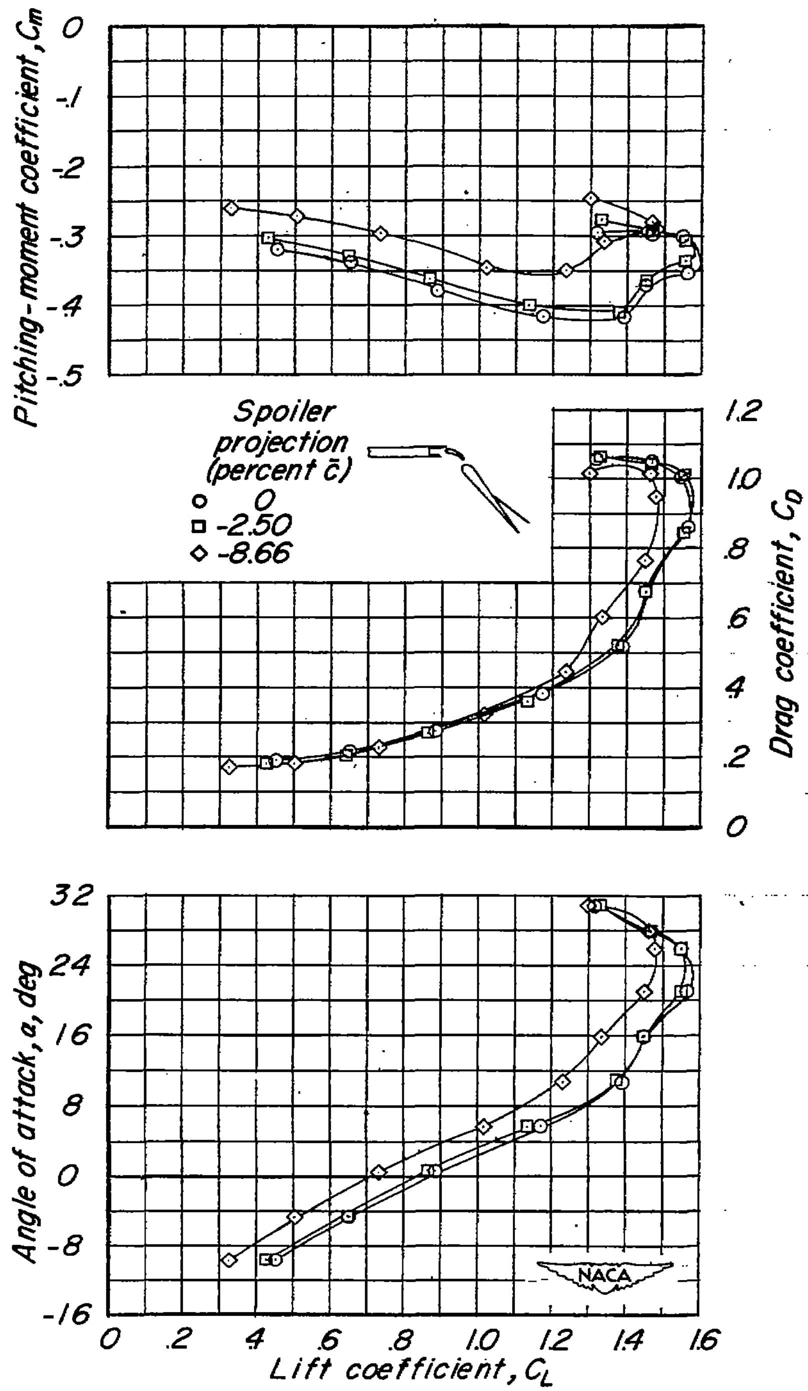


Figure 11.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54^\circ$). Spoilers hinged at rearward position and span extending from 0.094b/2 to 0.667b/2.

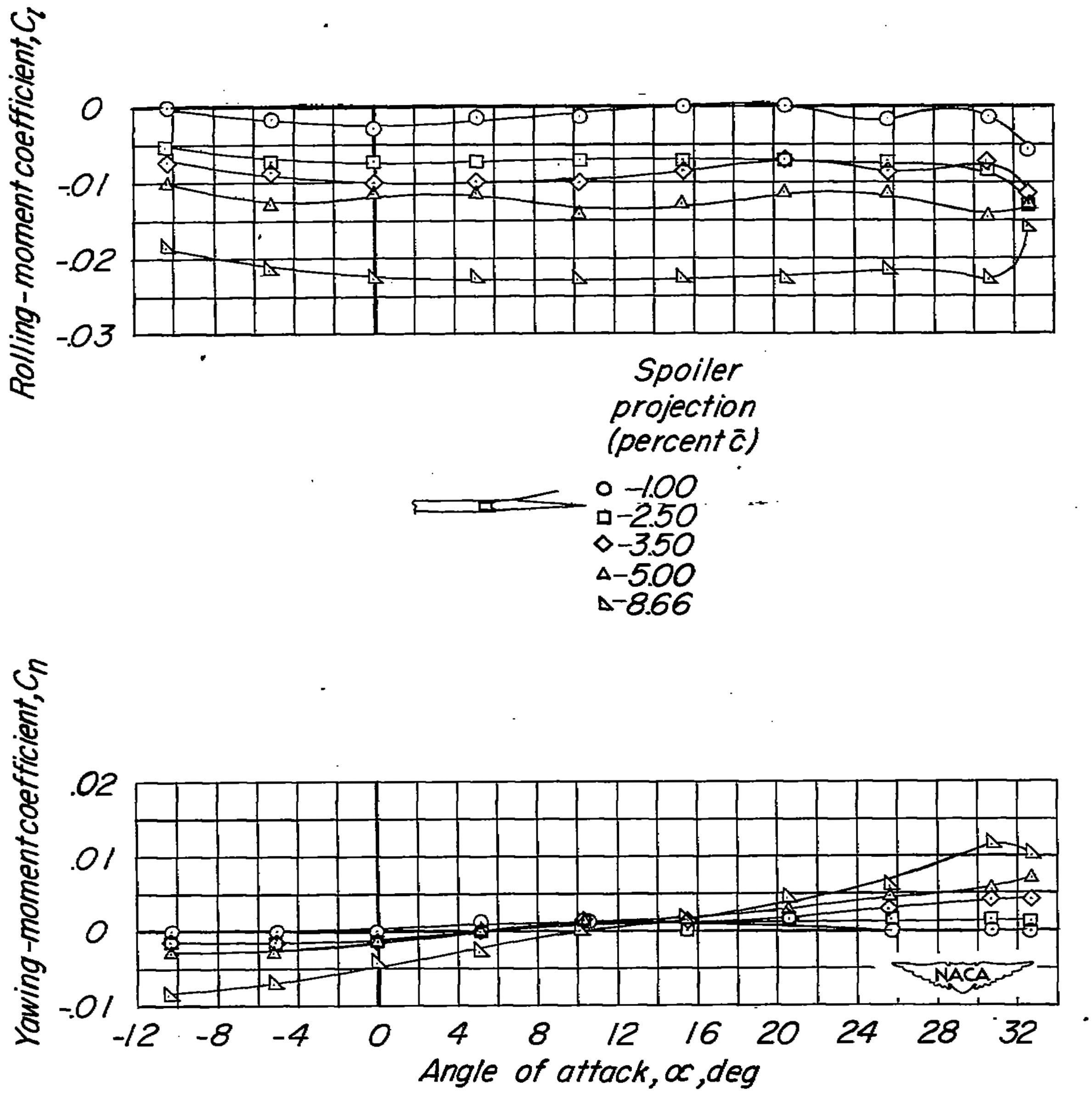


Figure 12.- Variation of rolling- and yawing-moment coefficients with angle of attack for several spoiler projections on 60° delta wing. Spoiler hinged at intermediate position and span extending from 0.094b/2 to 0.667b/2.

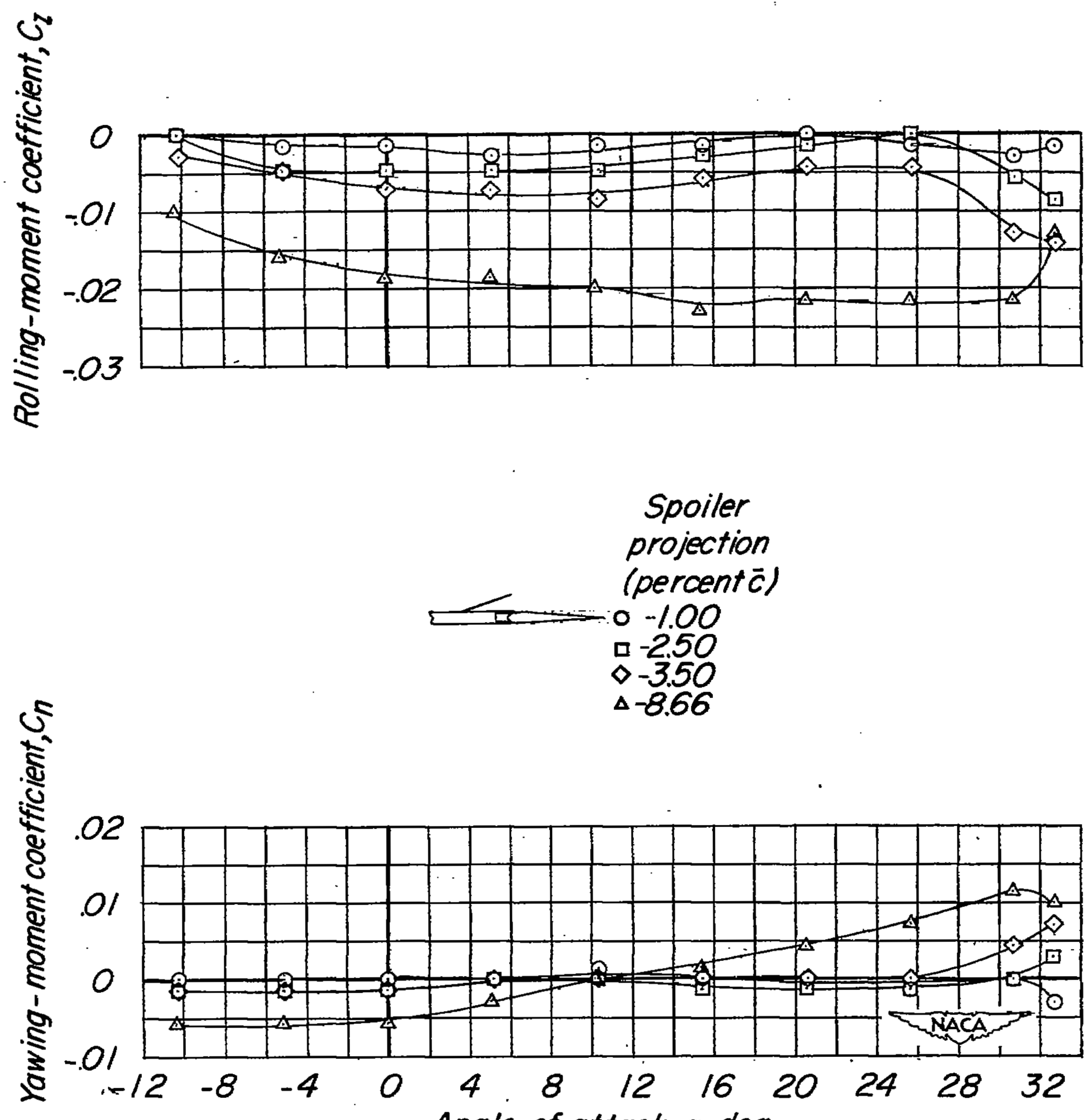


Figure 13.- Variation of rolling- and yawing-moment coefficients with angle of attack for several spoiler projections on 60° delta wing. Spoiler hinged at forward position and span extending from 0.094b/2 to 0.667b/2.

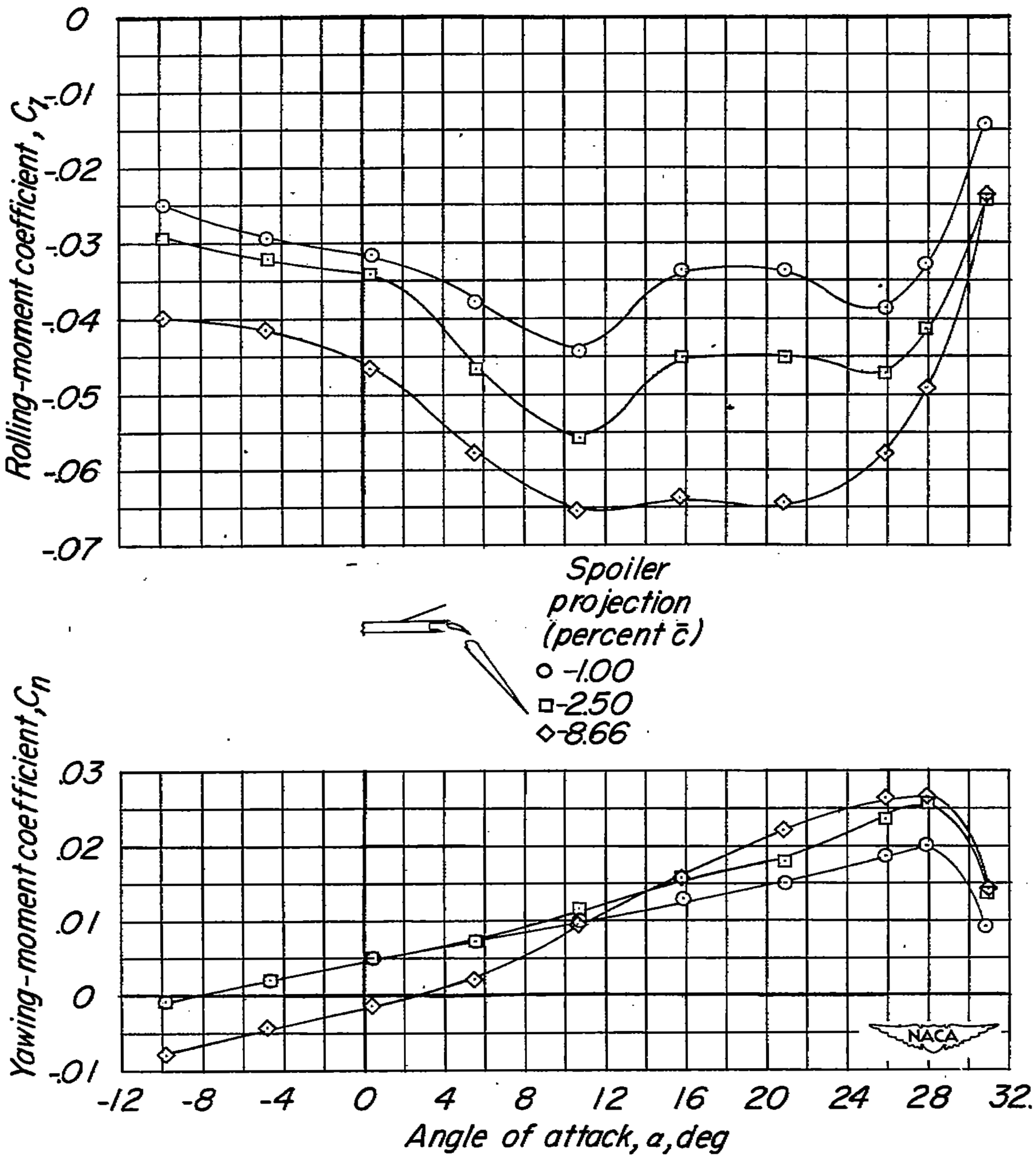


Figure 14.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54°$). Spoilers hinged at forward position and span extending from 0.094b/2 to 0.667b/2.

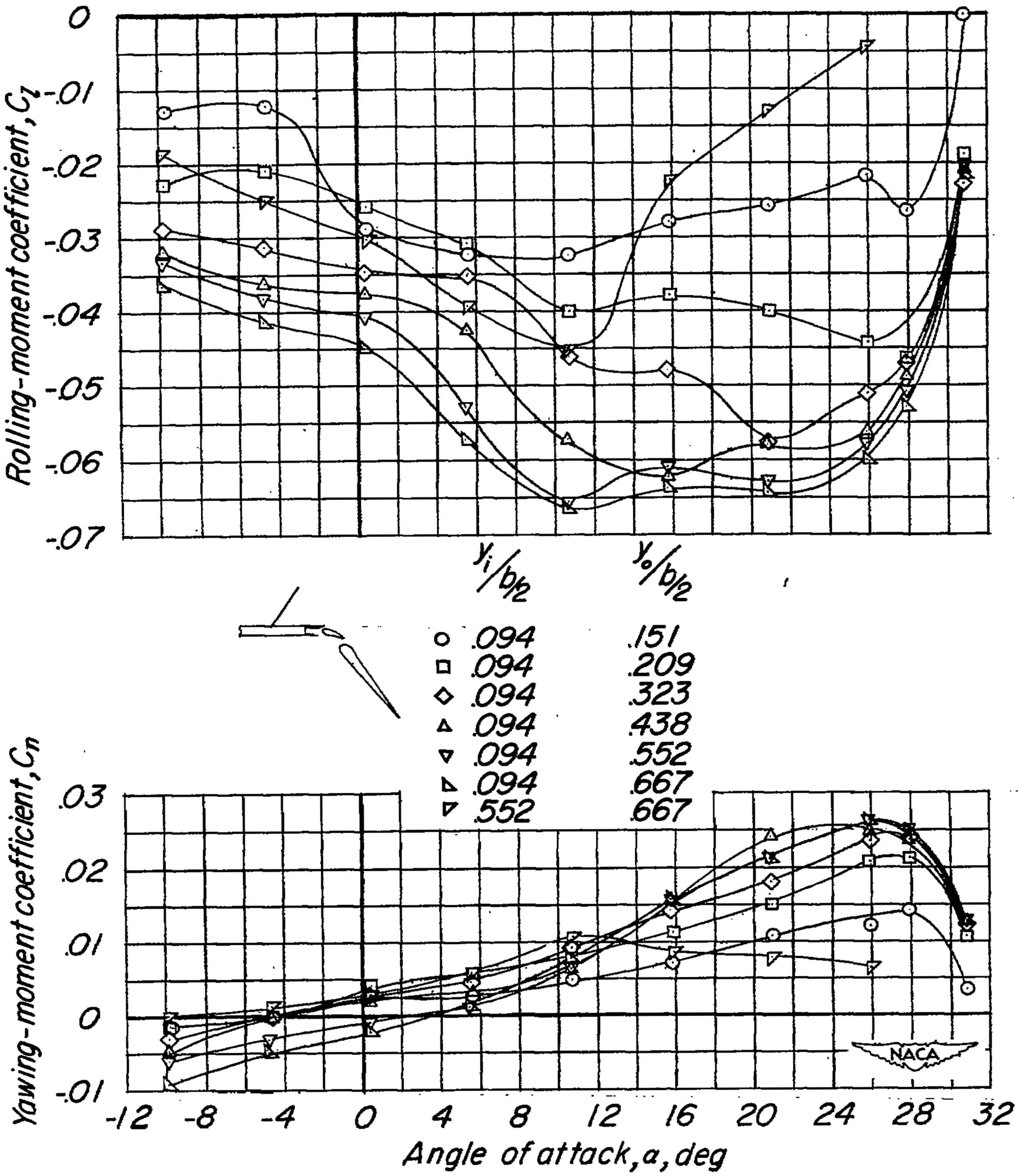


Figure 15.- Effects of spoiler span on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54°$). Spoilers projected at $0.0866\bar{c}$ and hinged at forward position.

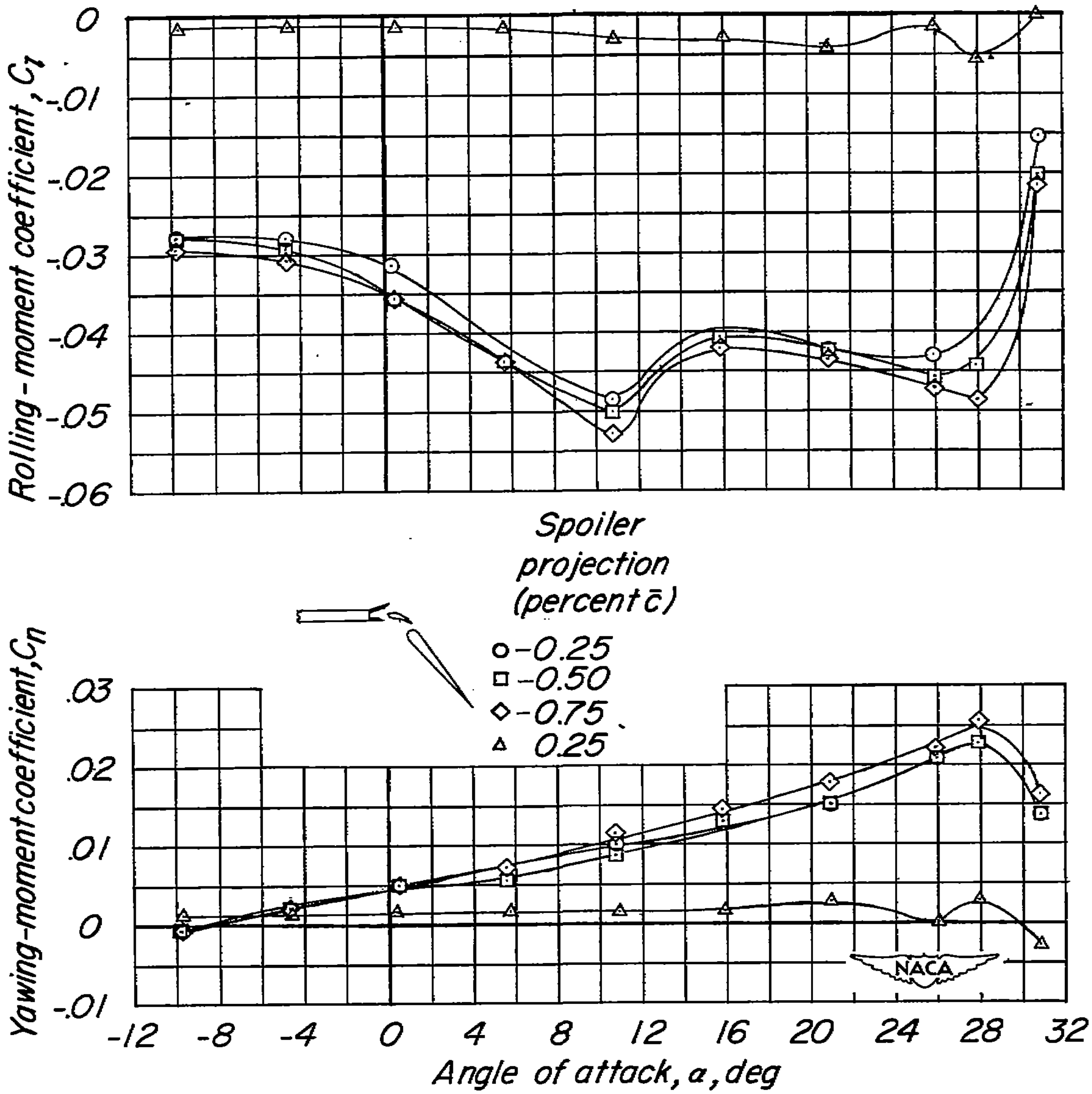


Figure 16.- Effects of deflecting lip of double-slotted flap 60° delta wing ($\delta_f = 54°$) on aerodynamic characteristics. Lip located at 88.6-percent-root-chord line and span extending from 0.094b/2 to 0.667b/2.

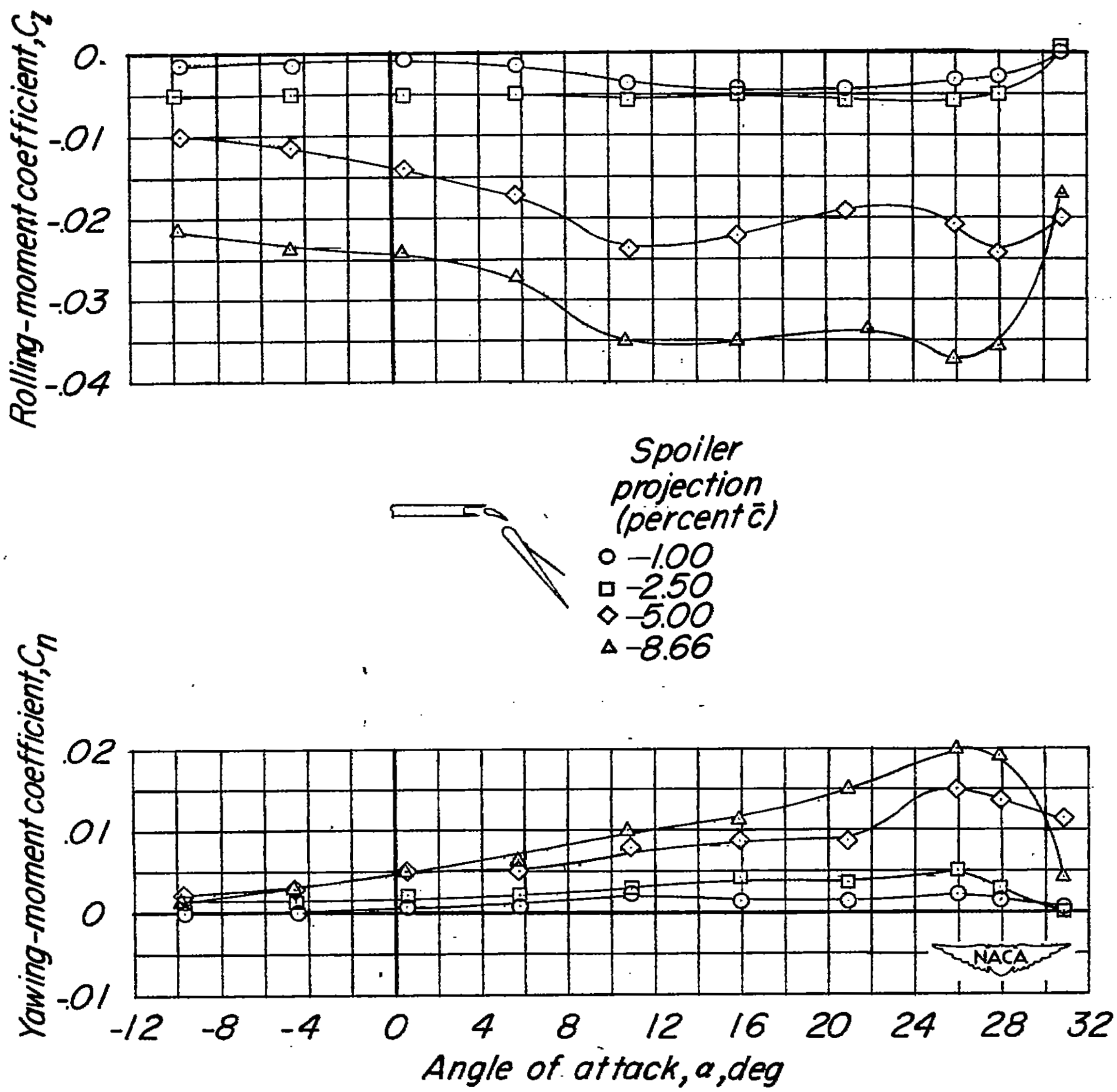


Figure 17.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54^{\circ}$). Spoilers hinged at intermediate position and spoiler span extending from 0.094b/2 to 0.667b/2.

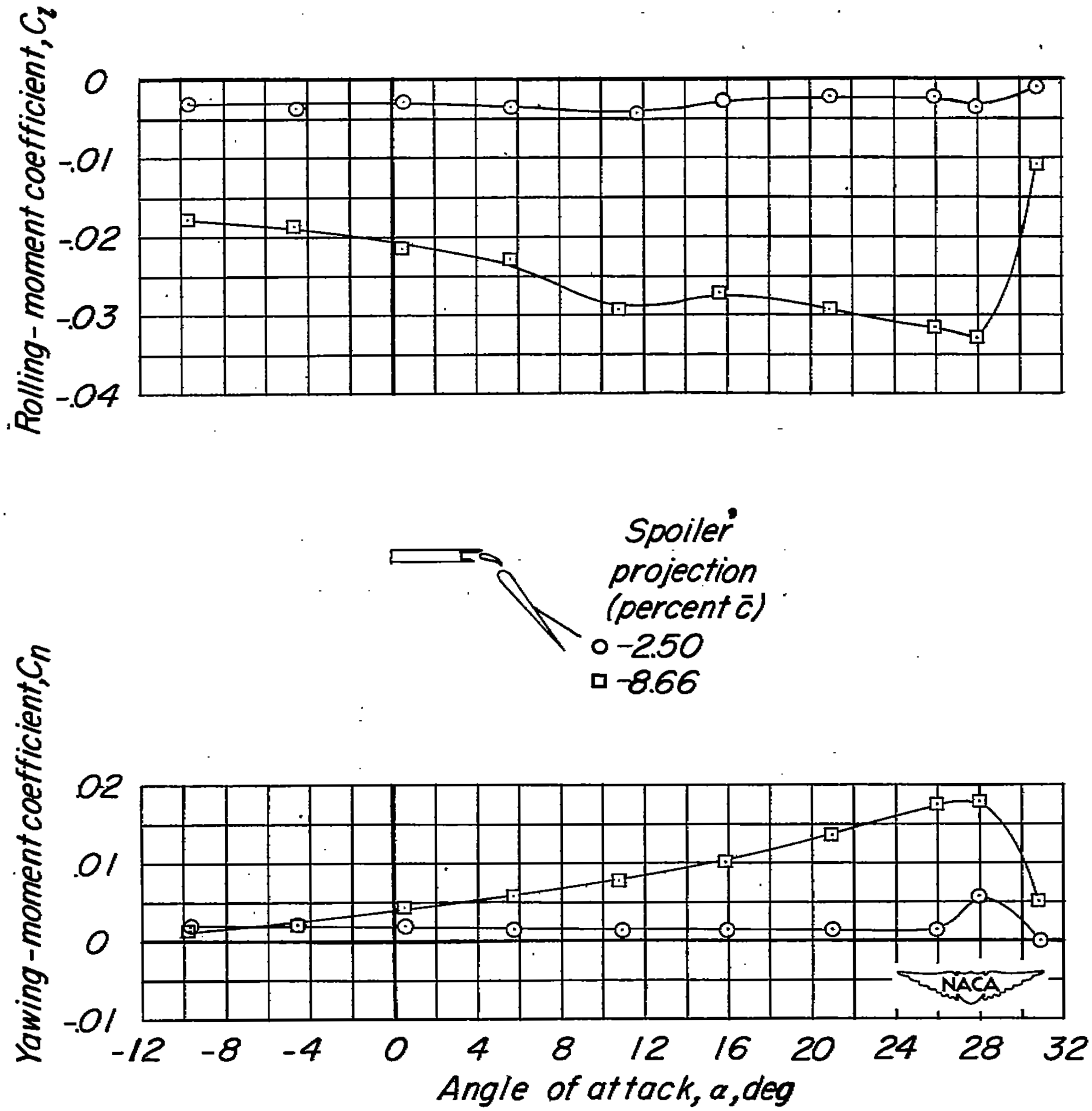
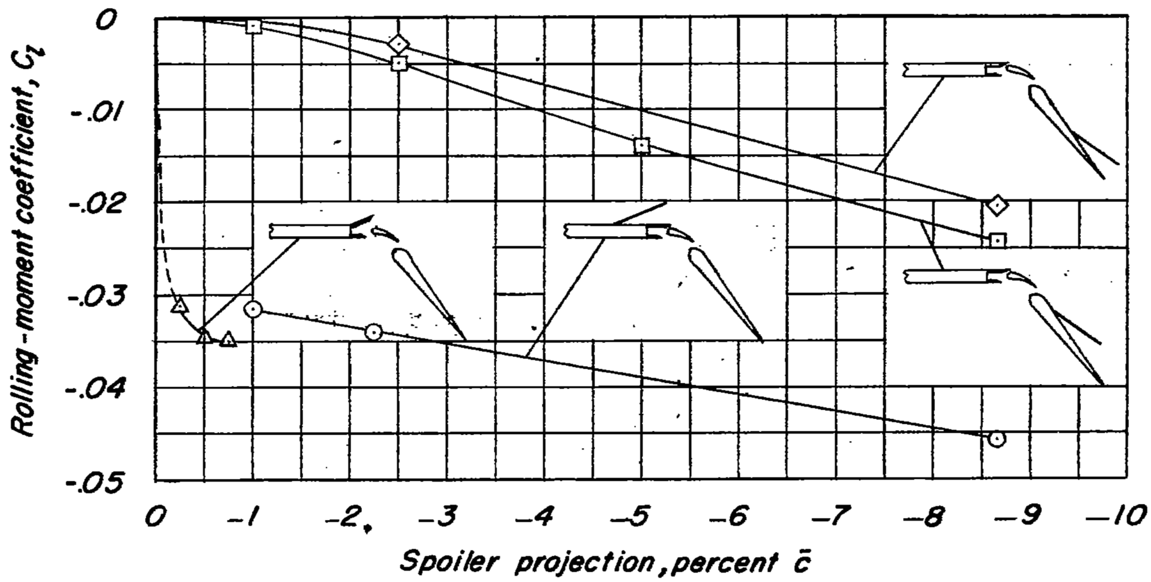
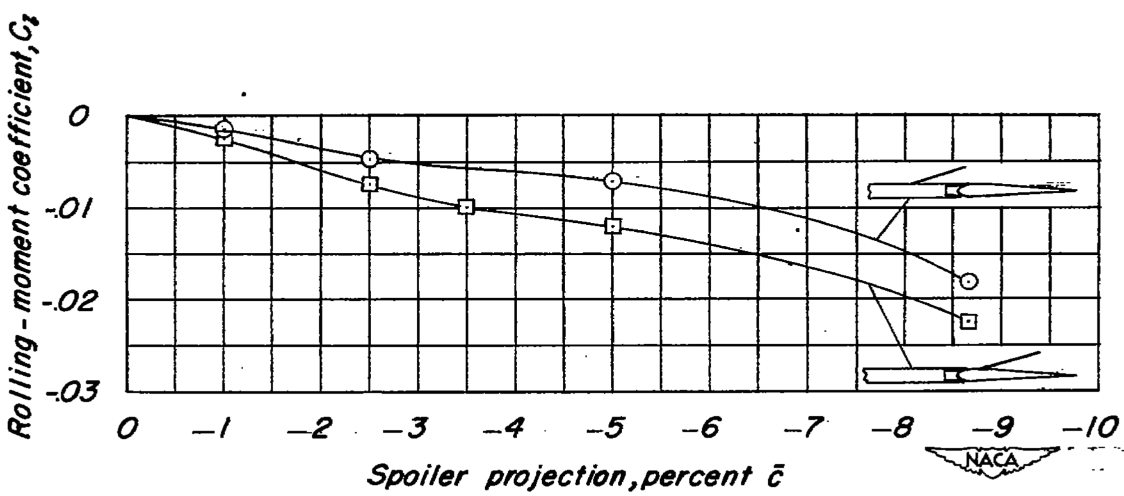


Figure 18.- Effects of spoiler projection on aerodynamic characteristics of 60° delta-wing model with double slotted flaps ($\delta_f = 54^\circ$). Spoilers hinged at rearward position and span extending from 0.094b/2 to 0.667b/2.



(b) Double-slotted-flap configuration with spoilers hinged at forward, intermediate, and rearward positions, and with lip deflected.



(a) 60° delta wing with spoilers hinged at forward and intermediate positions.

Figure 19.- Variation of rolling-moment coefficient with spoiler projection at $\alpha = 0^\circ$. Spoilers span extending from 0.094b/2 to 0.667b/2.

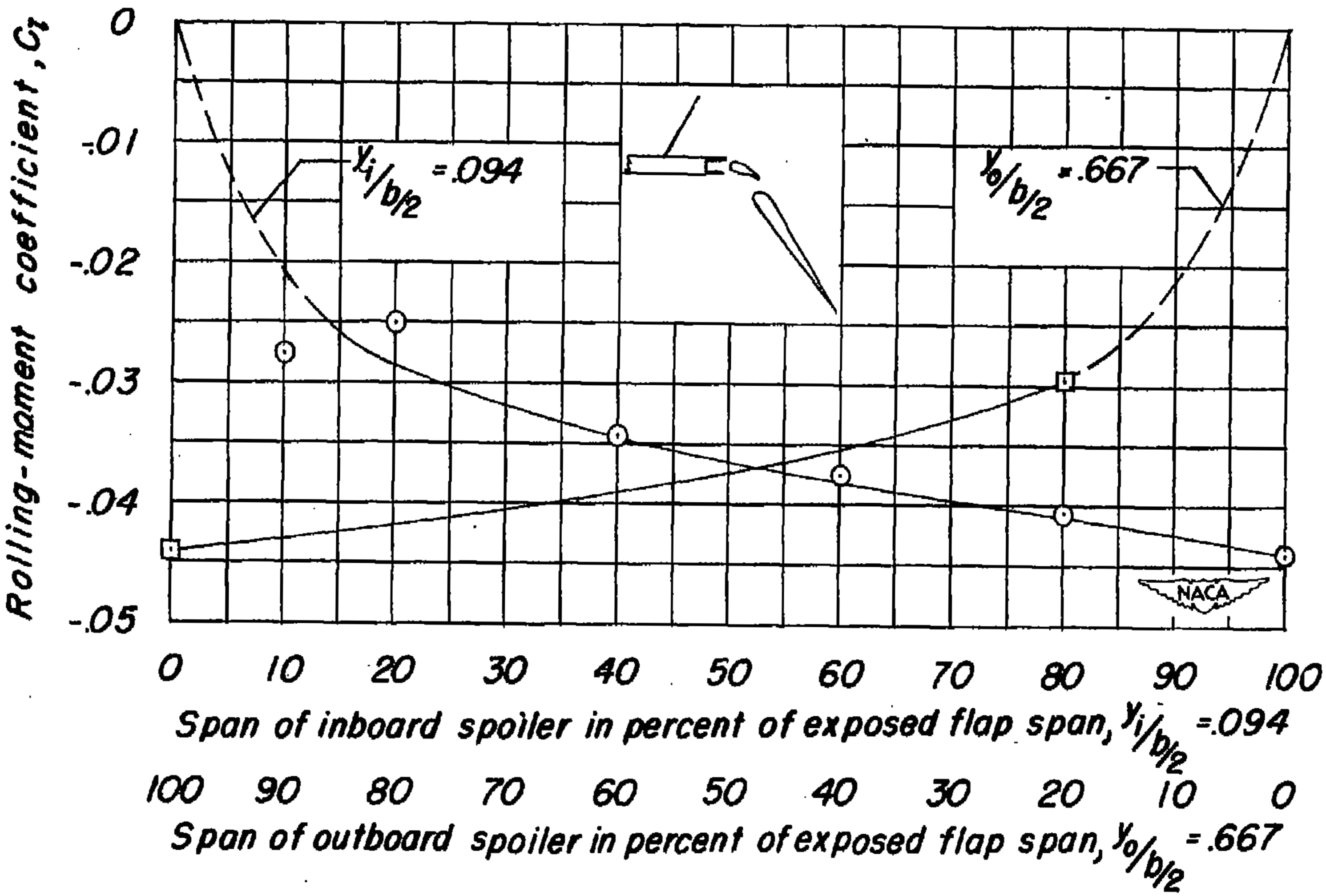


Figure 20.- Variation of rolling-moment coefficient with spoiler span of 60° delta-wing model with double slotted flaps ($\delta_f = 54^\circ$). Spoiler hinged at forward position ($\alpha = 0^\circ$).

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